

## OUTPUT BUFFER CIRCUIT

## BACKGROUND OF THE INVENTION

The present invention relates to an output buffer  
5 circuit provided in a semiconductor integrated circuit  
(hereinafter, referred to as an IC).

A usual output buffer circuit is constituted by a  
complementary MOS transistor (hereinafter, referred to as  
CMOS) IC. An inverter is connected to an input terminal  
10 receiving an input signal. The inverter includes a P-channel  
type MOS transistor (hereinafter, referred to as PMOS) and an  
N-channel type MOS transistor (hereinafter, referred to as  
NMOS) which are connected in series between a power source  
potential VDD node and a ground potential VSS node (i.e.,  
15 ground).

In designing an output buffer circuit, it is  
necessary to consider DC characteristics such as an output  
voltage and an output current of an output signal OUT. In  
order to satisfy the characteristics of the output voltage  
20 and output current, the PMOS and the NMOS are generally  
designed as large elements. However, when the PMOS and the  
NMOS have a large element size, rise and fall of the input  
signal IN causes a high-speed change of the rise and fall of  
the output signal OUT, generating an output waveform  
25 overshoot and undershoot. Moreover, for a short period of  
time, the PMOS and the NMOS simultaneously become an ON state,  
and a through current from the power source potential VDD to

the ground potential VSS increases, causing problems that the power consumption increases and the power source noise also increases.

Thus, in the conventional output buffer circuit, it is difficult to suppress the change of the output signal OUT to a low speed while satisfying the DC characteristic.

#### SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an output buffer circuit capable of suppressing the output signal change to a low speed while satisfying the DC characteristic.

According to the present invention, there is provided an output buffer circuit comprises an input terminal, an output terminal first and second inverters, a pull up control circuit, a pull down control circuit and first and second output transistors. Each of the first and second inverters is connected to the input terminal for outputting a signal having a slow rise up and fall down characteristic. Both of the pull up and pull down control circuits are connected to the input terminal and the output terminal. The pull up control circuit pulls up an output voltage of the first inverter when the output signal of the first inverter has a level lower than a first threshold voltage level. The pull up control circuit stops the pull up operation when the level of the output signal of the first inverter exceeds the first threshold voltage level. The pull down control circuit

pulls down an output voltage of the second inverter when the output signal of the second inverter has a level higher than a second threshold voltage level. The pull down control circuit stops the pull down operation when the pull down control circuit becomes lower than the second threshold voltage level. The first output transistor has a source connected to a first power source, a drain connected to the output terminal and a gate connected to the first inverter. The second output transistor has a source connected to a second power source, a drain connected to the output terminal and a gate connected to the second inverter.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram of an output buffer circuit according to a first embodiment of the present invention.

Fig. 2 is circuit diagram showing a configuration example of an inverter shown in Fig. 1.

Fig. 3 is a voltage waveform diagram showing operation of Fig. 2.

Fig. 4 is a voltage waveform diagram showing operation of Fig. 1.

Fig. 5 is a circuit diagram of an output buffer circuit according to a second embodiment of the present invention.

Fig. 6 is a voltage waveform diagram showing operation of Fig. 5.

Fig. 7 is a circuit diagram of a 3-state type output buffer circuit according to a third embodiment of the present invention.

Fig. 8 is a circuit diagram of a 3-state type output buffer circuit according to a fourth embodiment of the present invention.

Fig. 9 shows a fifth embodiment of the present invention showing another configuration example of the inverter in Fig. 1.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a circuit diagram of an output buffer circuit according to a first embodiment of the present invention.

This output buffer circuit is constituted by, for example, CMOS IC and has an input terminal 11 for inputting an input signal IN and this input terminal is connected to input terminals of a first and a second inverter 12 and 13. The input terminal 11 and an output terminal 20 for outputting an output signal OUT are connected to an input terminal of a 2-input NAND gate 14. The NAND gate 14 has an output terminal connected to a gate of an NMOS 16 for pull-up. The NMOS 16 has a drain connected to a first power source potential node (for example, power source potential VDD node), a source connected to an output side node N12 of the inverter 12, and a back gate connected to a second power source potential node (for example, ground potential VSS node).

The NAND gate 14 and the NMOS 16 constitute pull up control means. When the output signal OUT voltage is lower than a first threshold value voltage  $VT_{14}$  of the NAND gate 14, the pull up control means pulls up the voltage of the output side node N12 of the inverter 12, and when the output signal OUT voltage exceeds the first threshold value voltage  $VT_{14}$ , the pull up control means stops pull up of the voltage of the node N12 according to the input signal IN.

The input terminal 11 and the output terminal 20 are connected to an input terminal of 2-input NOR gate 15 and an output terminal of this NOR gate 15 is connected to a gate of PMOS 17 for pull down. The PMOS 17 has a source connected to the output side node N13 of the inverter 13, a drain connected to the ground potential VSS node, and a back gate connected to the power source potential VDD node.

The NOR gate 15 and the PMOS 17 constitute pull down control means. When the output signal OUT voltage exceeds a second threshold value voltage  $VT_{15}$ , the pull down control means pulls down the voltage of the output side node N13 of the inverter 13 and when the output signal OUT voltage becomes lower than the threshold value voltage  $VT_{15}$ , the pull down control means stops pull down of the voltage of the node N13 according to the input signal IN.

The NMOS 16 for pull up and the PMOS 17 for pull down are designed to have a large ON resistance in an ON state.

The node N12 is connected to a gate of a first

output transistor (for example, PMOS for output) 18. The PMOS 18 has a source and a back gate connected to the power source potential VDD node and a drain connected to the output terminal 20. The node N13 is connected to a gate of a second output transistor (for example, NMOS for output) 19. The NMOS 19 has a drain connected to the output terminal 20 and a source and a back gate connected to the ground potential VSS node.

Fig. 2 is a circuit diagram showing a configuration example of the inverter 12 in Fig. 1.

The inverter 12 has an input node Na connected to the input terminal 11 in Fig. 1 and this input node Na is connected to a gate of a first conductive type first MOS transistor (for example, PMOS) 12a and a gate of a second conductive type second MOS transistor (for example, NMOS) 12b. The PMOS 12a has a drain connected to the output node Nb, a source connected to a source of a first transistor (for example, NMOS) 12c, and a back gate connected to the power source potential VDD node. The NMOS 12c has a gate and a drain connected to the power source potential VDD node and a back gate connected to the ground potential VSS node. This NMOS 12c is diode-connected and the voltage fall (that is, threshold value voltage) is  $V_{Tn}$ .

The NMOS 12b has a drain connected to the output node Nb, a source connected to a source of a second transistor (for example, PMOS) 12d, and a back gate connected to the ground potential VSS node. The PMOS 12d has a drain

and a gate connected to the ground potential VSS node and a back gate connected to the power source potential VDD node. This PMOS 12d is diode-connected and the voltage fall (that is, the threshold value voltage) is  $V_{Tp}$ .

5        The inverter 13 in Fig. 1 has identical circuit configuration as the inverter 12 in Fig. 2.

Fig. 3 is a voltage waveform diagram showing operation of the inverter of Fig. 2. Furthermore, Fig. 4 is a voltage waveform diagram showing operation of the output  
10        buffer circuit of Fig. 1.

For example, when the voltage of the input signal IN supplied to the input terminal 11 in Fig. 1 falls down from the "H" level (= VDD) to the "L" level (= VSS), the output side nodes N12 and N13 of the inverters 12 and 13 rise up.

15        That is, in the inverter 12 of Fig. 2, as shown in Fig. 3, when the input signal IN voltage (voltage of the input node Na) falls from the "H" level to the "L" level from time  $t_{11}$  to time  $t_{14}$ , the PMOS 12a becomes an ON state and the NMOS 12b becomes an OFF state. Here, the potential  
20        difference between the source of the PMOS 12a and the power source potential VDD is not smaller than the threshold value voltage  $V_{Tn}$  of the NMOS 12c and accordingly, at time  $t_{12}$ , a large current flows in the diode-connected NMOS 12c and the voltage of the output node Nb rises up rapidly via the PMOS  
25        12a.

At time  $t_{13}$ , when voltage of the output node Nb becomes  $(VDD - V_{Tn})$ , the source voltage of the PMOS 12a

becomes equal to voltage ( $V_{DD} - V_{Tn}$ ). Accordingly, almost no current flows in the NMOS 12c and voltage of the output node Nb slowly rises up to the power source potential  $V_{DD}$ . That is, after time  $t_{13}$ , the potential difference applied to the NMOS 12c is not greater than the threshold value voltage  $V_{Tn}$ . Actually, however, leak current flows in this NMOS 12c and this leak current slowly increases the voltage of the output node Nb and the voltage reaches the power source potential  $V_{DD}$  at time  $t_{15}$ .

Thus, when the voltage of the input node Na falls from the "H" level to the "L" level, the voltage of the output node Nb rapidly increases to the ( $V_{DD} - V_{Tn}$ ) and slowly increases from this voltage ( $V_{DD} - V_{Tn}$ ) to the power source potential  $V_{DD}$ . The inverter 13 of Fig. 1 also operates in the same way as this inverter 12.

Moreover, when the input signal IN of Fig. 1 rises from the "L" level up to the "H" level, the PMOS 12a becomes the OFF state and the NMOS 12b becomes the ON state. Here, the potential difference between the source of the NMOS 12b and the ground potential VSS is not smaller than the threshold value voltage  $V_{Tp}$  of the PMOS 12d and accordingly, a large current flows in the diode-connected PMOS 12d and the voltage of the output node Nb rapidly falls down to  $V_{Tp}$ . When the voltage of the output node Nb becomes  $V_{Tp}$ , almost no current flows in the PMOS 12d and a leak current flowing in this PMOS 12d slowly lowers the voltage of the output node Nb down to the ground potential VSS.



Thus, voltage of the output node Nb rapidly falls from the power source potential VDD down to the voltage V<sub>TP</sub> and slowly falls from the voltage V<sub>TP</sub> down to the ground potential VSS. The inverter 13 of Fig. 1 also operates in the same way as this inverter 12.

Next, explanation will be given on the entire operation of the output buffer circuit of Fig. 1 with reference to Fig. 4.

For example, when the input signal IN voltage rises from the "L" level (= VSS) up to the "H" level (= VDD) at time t<sub>21</sub>, the output side nodes N12 and N13 of the inverters 12 and 13 fall down to the "L" level, and the PMOS 18 becomes the ON state and The NMOS 19 becomes the OFF state. Since the output signal OUT voltage is at "L" level when the output side node N12 of the inverter 12 falls down to the "L" level, the output voltage of the NAND gate 14 is at "H" level and the node N12 is pulled up by the NMOS 16 in the ON state. For this, the voltage divided by the pull up of the NMOS 16 and the inverter 12 is supplied to the gate of the PMOS 18. Since the PMOS 18 supplied with the divided gate voltage has a small drive capacity, the output signal OUT voltage slowly increases to the "H" level via this PMOS 18.

When the output signal OUT voltage increases to the threshold value voltage V<sub>T14</sub> of the NAND gate 14 at time t<sub>22</sub> in Fig. 4; the output voltage of the NAND gate 14 becomes "L" level and the NMOS 16 becomes the OFF state. This stops the pull up operation of the NMOS 16 and the output side node N12

of the inverter 12 becomes completely "L" level. Accordingly, the drive capacity of the PMOS 18 becomes large and the voltage of the output signal OUT rapidly rises via this PMOS 18 up to the "H" level ( $= V_{DD}$ ).

5           Moreover, when the voltage of the input signal IN falls from the "H" level to the "L" level, the output side nodes N12 and N13 of the inverters 12 and 13 rise up to the "H" level and the PMOS becomes the OFF state and the NMOS 19 becomes the ON state. Here, since the voltage of the output  
10   signal OUT is at "H" level, the output voltage of the NOR gate 15 becomes "L" level and the PMOS 17 becomes the ON state. When the PMOS 17 becomes the ON state, the output side node N13 of the inverter 13 is in a pulled down state and the divided voltage by the pull down of the inverter 13  
15   and the PMOS 17 is supplied to the gate of the NMOS 19.

          Since the NMOS 19 supplied with the divided gate voltage has a small drive capacity, the voltage of the output signal OUT is slowly falls down to the "L" level. When the voltage of the output signal OUT becomes lower than the  
20   threshold value voltage  $V_{15}$  of the NOR gate 15, the output voltage of this NOR gate 15 becomes "H" level, the PMOS 17 becomes the OFF state, and the pull down operation stops. Thus, the output side node N13 of the inverter 13 becomes completely "H" level and the drive capacity of the NMOS 19  
25   becomes large. The voltage of the output signal OUT rapidly falls down to become completely "L" level ( $= V_{SS}$ ).

          In the output buffer circuit of the present

embodiment, the NMOS 16 for pull up and PMOS 17 for pull down are designed to have a large ON resistance. The reason of this will be explained below.

5 In order to reduce the current flowing when dividing voltage between the inverters 12 and 13 and the NMOS 16 for pull up and the PMOS 17 for pull down, on resistance of the NMOS 16 and the PMOS 17 is set to a large value. Moreover, not only the current, but when the on resistance of the NMOS 16 and the PMOS 17 is set too small, the output voltage of the inverts 12 and 13 become lower than the threshold value  
10 voltage of the PMOS 18 and the NMOS 19 at the later stage and the circuit may not operate. Accordingly, the on resistance of the NMOS 16 and the PMOS 17 is set to a large value.

The inverter 12 of Fig. 2 includes the diode-  
15 connected NMOS 12c and PMOS 12d and accordingly, voltage of the output node Nb of this inverter 12, 13 slowly changes between the power source potential VDD and voltage ( $VDD - V_{Tn}$ ) and between the ground potential VSS and the voltage  $V_{Tp}$ . For this, the voltage of the output signal OUT also changes  
20 slowly. Thus, it is possible to prevent generation of overshoot and undershoot of the output signal OUT.

In Fig. 1, by the pull up operation by the NMOS 16 and the pull down operation by the PMOS 17, firstly, the voltage of the output signal OUT slowly changes because the  
25 drive capacity of the PMOS 16 and the NMOS 17 is set small. After this, the pull up operation or the pull down operation is stopped and the drive capacity of the PMOS 18 and the NMOS

19 is set large so as to rapidly change the voltage of the output signal OUT. This can prevent through current flowing from the power source potential VDD via the PMOS 18 and the NMOS 19 to the ground potential VSS. This reduces the power consumption and prevents the power source noise.

Fig. 5 is circuit diagram showing an output buffer circuit according to a second embodiment of the present invention. Like components as in the first embodiment of Fig. 1 are denoted by like reference symbols.

This output buffer circuit is constituted, for example, by a CMOS IC and differs from the output buffer circuit of Fig. 1 in that the NAND gate 14 and the NOR gate 15 of Fig. 1 are replaced by delay circuits 24 and 25 having predetermined delay time values DT.

Each of the delay circuits 24 and 25 includes, for example, three-stage inverters connected in the longitudinal direction. The delay circuit 24 has an input terminal connected to the input terminal 11 and an output terminal connected to the gate of the NMOS 16 for pull up. The other delay circuit 25 has an input terminal connected to the input terminal 11 and an output terminal connected to the gate of the PMOS 17 for pull down. The delay circuit 24 and the NMOS 16 constitute pull up control means. The delay circuit 25 and the PMOS 17 constitute pull down control means.

In the first embodiment shown in Fig. 1, the NAND gate 14, the NOR gate 15, the NMOS 16, and the PMOS 17 are used to control pull up and pull down of the nodes N12 and

N13 by the feed back from the output signal OUT. In contrast to this, in the second embodiment, the delay circuits 24 and 25, the NMOS 16, and the PMOS 17 are used to control pull up and pull down of the nodes N12 and N13 by the delay time DT.

5 The other configuration portion is identical to the first embodiment.

Fig. 6 is a voltage waveform diagram showing operation of Fig. 5.

For example, when the input signal IN rises from the

10 "L" level (= VSS) to the "H" level (= VDD) at time t21, the output side nodes N121 and N13 of the inverters 12 and 13 fall down to the "L" level and the PMOS becomes the ON state and the NMOS 19 becomes the OFF state. When the output side node N12 of the inverter 12 falls down to the "L" level,

15 since the delay time DT of the delay circuit 24 is present, the output voltage of the delay circuit 24 is still at the "H" level and the NMOS 16 for pull up is in the ON state. Accordingly, the voltage divided by the inverter 12 and the NMOS 16 becomes voltage of the output side node N12 of the

20 inverter 12. The PMOS 18 supplied with this divided voltage has a drive capacity made smaller and the voltage of the output signal OUT is slowly rises up to the "H" level via the PMOS 18.

At time t22 after the time lapse of the delay time

25 DT from the time t21, the output voltage of the delay circuit 24 falls down to the "L" level. Accordingly, the NMOS 16 becomes the OFF state and the voltage of the output side node

N12 of the inverter 12 becomes completely "L" level. Thus, the PMOS 18 has a large drive capacity and the voltage of the output signal OUT rapidly rises via the PMOS 18 up to the "H" level (= VDD).

5           Moreover, when the output signal IN falls from the "H" level down to the "L" level, the output side nodes N12 and N13 of the inverters 12 and 13 rise up to the "H" level and the PMOS 18 becomes the OFF state and the NMOS 19 becomes the ON state. When the output side node N13 of the inverter  
10 13 rises up to the "H" level, the output voltage of the delay circuit 25 is still at the "L" level by the delay time DT of the delay circuit 25 and the PMOS for pull down is in the ON state. Accordingly, the voltage divided by the inverter 13 and the PMOS 17 becomes voltage of the output side node N13  
15 of the inverter 13. The NMOS 19 supplied with this divided voltage has a drive capacity made smaller and voltage of the output signal OUT slowly falls down to the "L" level via the NMOS 19.

          Next, when the output voltage of the delay circuit  
20 25 becomes "H" level with delay of the delay time DT, the PMOS 17 becomes the OFF state and voltage of the output side node N13 of the inverter 13 also becomes completely "H" level. Thus, the drive capacity of the NMOS 19 becomes large and voltage of the output signal OUT rapidly falls down via the  
25 NMOS 19 completely to the "L" level (= VSS).

          In this second embodiment, like in the first embodiment, it is possible to make the change of the output

signal OUT at a low speed and prevent through current flowing in the PMOS 18 and the NMOS 19. Thus, it is possible to reduce the power consumption and noise while maintaining the DC characteristic of the conventional output buffer circuit.

5 Moreover, in this embodiment, since pull up and pull down of the output side nodes N12 and N13 of the inverters 12 and 13 are controlled by the delay time DT of the delay circuits 24 and 25, it is possible to control the drive capacity of the PMOS 18 and the NMOS 19 without being affected by voltage of  
10 the output signal OUT and it becomes easy to design the circuit.

Fig. 7 a circuit diagram showing a 3-state type output buffer circuit according to a third embodiment of the present invention. Like components as in the first  
15 embodiment are denoted by like reference symbols.

This 3-state type output buffer circuit is constituted, for example, by a CMOS IC. A gate circuit is provided at the input side of the output buffer circuit of Fig. 1 and when an enable signal EN is at "L" level for  
20 example, the output terminal 20 becomes a high impedance state.

The gate circuit includes input terminals 31 and 32 for inputting the enable signal EN, an inverter 33, a 2-input AND gate 34, and a 2-input OR gate 35. Moreover, the 2-input  
25 NAND gate 14 in Fig. 1 is replaced by a 3-input NAND gate 14A, and the 2-input NOR gate 15 in Fig. 1 is replaced by a 3-input NOR gate 15A.

The input terminal 31 and the input terminal 11 are connected to an input terminal of the AND gate 34 whose output terminal is connected to an input terminal of the inverter 12. The input terminal 32 is connected to an input terminal of the inverter 33 and the output terminal of the inverter 33 and the input terminal 11 are connected to the input terminal of the OR gate 35 whose output terminal is connected to an input terminal of the inverter 13. The input terminal 31, the output terminal of the AND gate 34, and the output terminal 20 are connected to the input terminal of the NAND gate 14A, and the output terminal of this NAND gate 14A is connected to the gate of the NMOS 16 for pull up. The output terminal of the inverter 33, the output terminal of the OR gate 35, and the output terminal 20 are connected to the input terminal of the NOR gate 15A and the output terminal of this NOR gate 15A is connected to the gate of the PMOS 17 for pull down. The other configuration portion is identical to the output buffer circuit of Fig. 1.

For example, when the enable signal EN supplied to the input terminals 31 and 32 is made "H" level, the AND gate 34, the OR gate 35, the NAND gate 14A, and the NOR gate 15A are opened. Then, the input signal IN supplied to the input terminal 11 is transmitted via the AND gate 34 to the inverter 12 and the NAND gate 14A, and via the OR gate 35 to the inverter 13 to the NOR gate 15A. Accordingly, like in the output buffer circuit of Fig. 1, when the voltage of the input signal IN falls from the "H" level down to the "L"



level, voltage of the output signal OUT also falls from the "H" level down to the "L" level, and when the voltage of the input signal IN rises from the "L" level up to the "H" level, the voltage of the output signal OUT also rises from the "L" level up to the "H" level. That is, when the enable signal EN is at "H" level, operation identical to that of the output buffer circuit of Fig. 1 is performed.

Moreover, when the enable signal EN is at "L" level, the AND gate 34, the OR gate 35, the NAND gate 14A, and the NOR gate 15A are closed; output voltage of the AND gate 34 is fixed to "L" level; output voltage of the OR gate 35 is fixed to "H" level; output voltage of the NAND gate 14A is fixed to "H" level; and output voltage of the NOR gate 15A is fixed to "L" level. Accordingly, the output side node N12 of the inverter 12 is fixed to "H" level and the output side node N13 of the inverter 13 is fixed to "L" level. The "H" level output voltage of the NAND gate 14A makes the NMOS 16 in the ON state and the "L" level output voltage of the NOR gate makes the PMOS 17 in the ON state. Accordingly, the node N12 is pulled up to the "H" level and the node N13 is pulled down to the "L" level. The PMOS 18 and NMOS 19 become the OFF state and the output terminal 20 becomes a Hiz state.

In this embodiment, it is possible to make the output terminal 20 in the Hiz state by the enable signal EN. Accordingly, besides the effects of the first embodiment, it is possible to obtain the 3-state type that improves usage.

Fig. 8 is a circuit diagram showing a 3-state type

output buffer circuit according to a fourth embodiment of the present invention. Like components as in the second embodiment of Fig. 5 and the third embodiment of Fig. 7 are denoted by like reference symbols.

5           This 3-state type output buffer circuit is constituted, for example, by a CMOS IC. At the input side of the output buffer circuit of Fig. 7, a gate circuit consisting of input terminals 31 and 32 of Fig. 7, the AND gate 34, and the OR gate 35 is provided and the output  
10          terminal 20 becomes a high impedance state when the enable signal EN is at "L" level for example.

          The input terminal 31 supplied with the enable signal EN and the input terminal 11 supplied with the input signal IN are connected to the input terminal of the AND gate  
15          34 and the output terminal of this AND gate 34 is connected to the input terminal of the inverter 12 and the input terminal of the delay circuit 24. The input terminal 32 supplied with the enable signal EN is connected to the input terminal of the inverter 33. The output terminal of the  
20          inverter 33 and the input terminal 11 are connected to the input terminal of the OR gate 35, and the output terminal of this OR gate 35 is connected to the input terminal of the inverter 13 and the input terminal of the delay circuit 25. The other configuration portion is identical to the output  
25          buffer circuit of Fig. 5.

          For example, when the enable signal EN supplied to the input terminals 31 and 32 is at "H" level, the AND gate

34 and the OR gate 35 are opened and the input signal IN supplied from the input terminal 11 is transmitted via the AND gate 34 to the inverter 12 and the delay circuit 24 and via the OR gate 35 to the inverter 13 and the delay circuit 25. Thus, operation identical to the output buffer circuit Fig. 5 is performed.

Moreover, when the enable signal EN is at "L" level, the AND gate 34 and the OR gate 35 are closed; the output terminal of this AND gate 34 is fixed to "L" level; and the output terminal of the OR gate is fixed to "H" level. Accordingly, the output side node N12 of the inverter 12 is fixed to "H" level and the output side node N13 of the inverter 13 is fixed to "L" level, the PMOS 18 and NMOS 19 become the OFF state, and the output terminal 20 becomes the HiZ state.

In this embodiment, it is possible to make the output terminal 20 at the high impedance state by controlling the enable signal EN. Accordingly, besides the effects obtained by the second embodiment, it is possible to obtain a 3-state type that improves usage.

Fig. 9 shows a fifth embodiment of the present invention. The inverter 12 in Fig. 1 is replaced by an inverter of another configuration. Like components as in the first embodiment of Fig. 2 are denoted by like reference symbols.

In this inverter 120, the diode-connected NMOS 12c of Fig. 2 is replaced by a first diode 42c, and the diode-

connected PMOS 12d of Fig. 2 is replaced by a second diode 42d. The diode 42c is connected between the power source potential VDD node and the source of the PMOS 12a in the forward direction. The diode 42d is connected between the source of the NMOS 12b and the ground potential VSS node in the forward direction. The other configuration portion is identical to the circuit of Fig. 2.

For example, it is assumed that the voltage fall of the diodes 42c and 42d is  $V_{Tdio}$ . In the inverter 120 of the present embodiment, the diode 42c and 42d operate almost in the same way as the NMOS 12c and PMOS 12d in Fig. 4. Accordingly, when the input voltage is supplied to the input node Na, the output voltage of the output node Nb slowly changes in a voltage range between the ground potential VSS and the voltage  $|V_{Tdio}|$  and a voltage range between the power source potential VDD and a voltage  $(VDD - |V_{Tdio}|)$ . Consequently, the voltage of the output signal OUT of Fig. 1 also changes at a low speed.

In this embodiment, like the inverter 12 (or 13) of the first embodiment of Fig. 2, it is possible to slowly change the voltage of the output signal OUT. For this, like the inverter 12 (or 13) in Fig. 2, it is possible to prevent generation of the output waveform overshoot and undershoot and to prevent generation of power source noise due to output current.

The present invention is not limited to the aforementioned embodiments but may be modified in various

ways. For example, modifications (i) to (iv) as follows can be performed.

(i) In the inverter of Fig. 2 and Fig. 9, the PMOS may be replaced by an NMOS and the NMOS may be replaced by a PMOS. Corresponding to this, the power source potential VDD and the ground potential VSS may have reverse polarity. Alternatively, the PMOS and the NMOS may be constituted by transistors such as bipolar transistors.

(ii) The pull up control means and the pull down control means of Fig. 1 and Fig. 2 may be constituted by other gate circuit or transistor.

(iii) The pull up control means and the pull down control means of Fig. 5 and Fig. 8 may be constituted by a delay circuit and a transistor of other configuration.

(iv) The PMOS 18 and the NMOS 19 for output in the embodiment may be replaced by an NMOS and a PMOS, respectively, by changing the polarity of the power source potential. Moreover, these may also be constituted by other output transistors such as bipolar transistors.